IMAGE RECONSTRUCTION METHODS FOR ELECTRICAL IMPEDANCE TOMOGRAPHY ON SUT-1 SYSTEM

M. Soleimani[1], A. Movafeghi[2]
[1]University of Manchester, Institute of Science and Technology UMIST, UK mcbijms3@fs2.umist.ac.uk
[2]Department of Mechanical Engineering, Sharif University of Technology, Tehran, Iran amov@mehr.sharif.edu

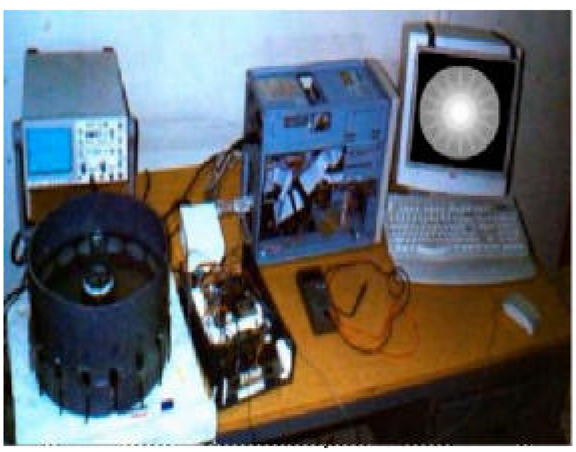
Abstract - **In this paper we describe some software for image reconstruction of electric impedance tomography (EIT) made on Sharif University of Technology named (SUT-1). We will discuss about image reconstruction methods and we will show the results of simulation and real measurement from SUT-1 system.**

Keywords - **Electrical Impedance Tomography, Image Reconstruction, Inverse Problem**

I. INTRODUCTION

SUT-1 is a 32 electrodes electrical impedance tomograph that was designed and fabricated in Sharif University of Technology. In Fig. 1. general view of this system was showed. Information about hardware and main specification of system and some results and also software for solving forward problem by FEM was introduced before [1,2,3,4,5]. The main objective of this paper is discussion about some image reconstruction methods for EIT; presenting some results from image reconstruction software based on such methods and verification of software with simulation and actual test data from SUT-1.

Fig. 1. General view of SUT-1



II. METHODOLOGY

Image in EIT is mapping of conductivity distribution, by means of observation of electric potential (measurement of voltage) in the finite number of points in the surface of object that such potentials made by injection current to media. The sensors for injection current and sensing voltages are electrodes.

1) *Mathematical Model*:

$$\nabla.\left[\tilde{d}(P).\nabla\tilde{U}(P)\right]=0 \text{ at B (B is the object)} \quad (1)$$

$$\tilde{d}(P)\frac{¶\tilde{U}(P)}{¶n}=J \qquad P\in S \text{ (Surface)} \quad (2)$$

$$\int_S \tilde{U}(P)ds=0 \qquad P\in S \quad (3)$$

where $\tilde{U}(P)$ is voltage and $\tilde{d}(P)$ is specific admittance of B; in which:

$$\tilde{d}(P)=d(P)+jwe(P) \qquad \text{S is surface boundary of B}$$

These equations are derived form of Maxwell s Equations with some approximation and an elliptic partial differential equation with Neumann boundary condition and with low frequency approximation of current injection in conductive media. As described above for solving this equation in forward problem FEM is used.

2) *Image Reconstruction Methods*: Most important subject in EIT is its image reconstruction, because image reconstruction in EIT is an ill-posed inverse problem. From the time of advent EIT in 1983 very much works were made in EIT image reconstruction and this kind of effort is continued up to now. For reconstruction in mode of static imaging a modified NewtonRaphson Method with 32 electrodes was implemented. In this approach we interested in minimizing the function ϕ with respect to σ defined as follows:

$$f=\frac{1}{2}(f-V)^T(f-V) \qquad (4)$$

V is measured voltages and f is forwad problem results.

The minimization of ϕ turns out to be the Newton iteration which is shown in this equation, This is simply an update for σ:

$$\Delta s_k=-[f'(s_k)^T f'(s_K)]^{-1} f'(s_k)^T[f(s_K)-V] \quad (5)$$

For image reconstruction with this method some regularization needed [6]. And also sensitivity method used for image reconstruction. It uses a theorem derived by Geselowitz [7]. The theorem is best described using Fig. 2 . When the conductivity distribution changes from **s** to **s + Ds** the transfer impedance change **DZ** for the pairs of current and voltage electrodes (A,B) and (C,D) can be given as:

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Image Reconstruction Methods for Electrical Impedance Tomography on SUT-1 System	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) University of Manchester Institute of Science and Technology UMIST, UK	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
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$$\Delta Z = -\int_{\Omega} \Delta s \, \frac{\nabla u(s)}{I_u} \cdot \frac{\nabla v(s + \Delta s)}{I_v} d\Omega \quad (6)$$

where u is the potential distribution over the field when the current $\boldsymbol{I_u}$ is applied at (A,B) with a conductivity of $\mathbf{s}$. Likewise v is the potential over the field when the current $\boldsymbol{I_v}$ is applied at (C,D) with a conductivity of $\mathbf{s + Ds}$. This functional is used to help us solve the inverse problem in the following manner. We guess a conductivity, ($\mathbf{s}$), and calculate u given $\boldsymbol{I_u}$ in the forward problem. Taking the difference between the calculated u and the measured v will tell us **DZ,** using this we should be able to solve for **Ds** and hence find the conductivity distribution.

A method implemented for image reconstructed based on Neural Network, another method is based on genetic algorithm direct mapping of vector of voltage to conductivity was tried but the computation time for image reconstruction is very high, however some researcher used these methods for image reconstruction in EIT. Other one is based on perturbation method. This iterative technique was based on the application of known voltage patterns and measurement of current:

$$\frac{1}{c_i^n} = \frac{1}{c_i^{n-1}} + K \cdot \sum_{j=1}^{m} \frac{R C_j^n S_{ij}}{\sum_{k=1}^{m} |S_{ik}|} \left(\frac{1}{c_i^{n-1}} \right) \quad (7)$$

This method was implemented by Kim [10].

Another Image reconstruction method is Double Constraint Method. And also Layer Stripping Method is other way. Also DSM (Direct Sensitivity Method) is suitable for small perturbation detecting in conductivity. A very fast image reconstruction method with using one step of Newton-Raphson and solving forward problem by analytical method is implemented this method is named by NOSER [8]. Also a fast image reconstruction developed, this method is Broyden Quesi Newton Method [9] that was introduced before. We developed a mixed image reconstruction based on Broyden and modified Newton methods that in first step of image reconstruction modified Newton Rophson algorithm is used and the near of solution Broyden method.

For dynamic imaging mode of operation, image reconstruction was performed with 16 electrodes using Back Projection algorithm and iso-potential lines. Basically it was a *Sheffield Algorithm* with some improvement and modification for matching with SUT-1 system characteristics.

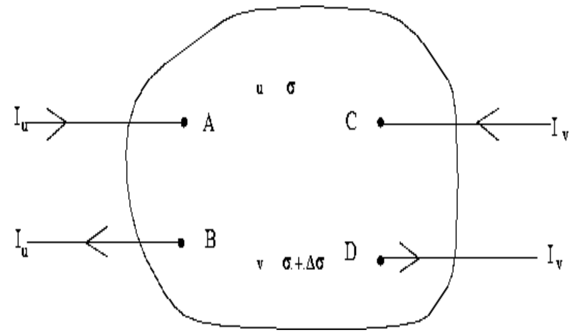

Fig. 2. Sensitivity Theorem

III. RESULTS

We measured voltage and reconstructed images in the real case both in 16 and 32 electrodes. Fig. 3. parts a-f show some of results both from simulated and real data. Fig. 3a and 3f illustrate two of the actual images using a simple phantom in dynamic mode. The phantom was made of PVC and electrodes were Ag/AgCl. Star artifact could be observed in the image resulted from back-projection.

IV. CONCLUSION

In this paper, we discuss about image reconstruction methods in EIT and also some image reconstruction software implemented for SUT-1 a 32 electrode EIT system that made based on such methods is introduced. Verification of software in simulation and actual data from SUT-1 system was showed.

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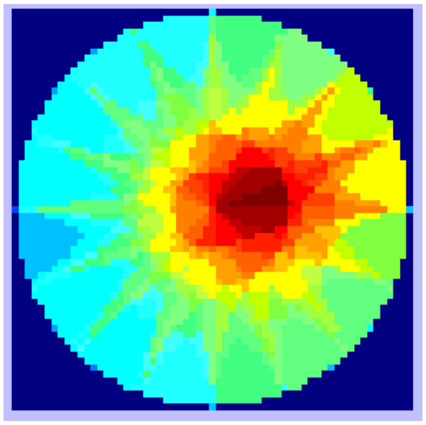
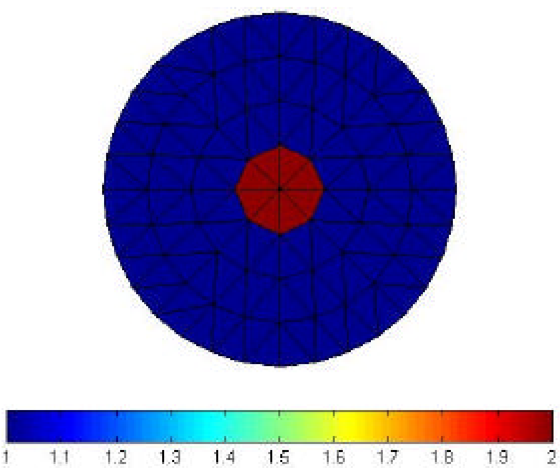
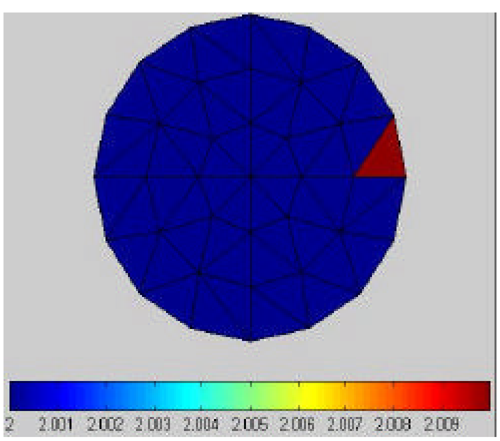


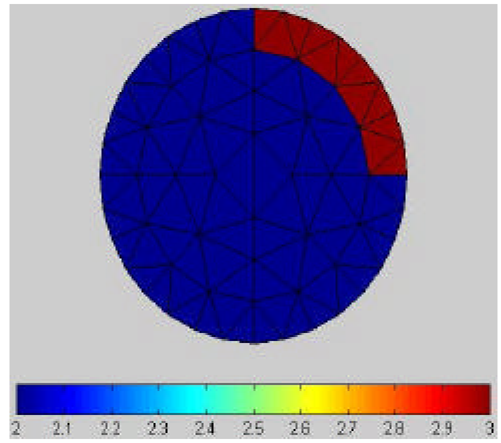
a. A simulated image with BP method



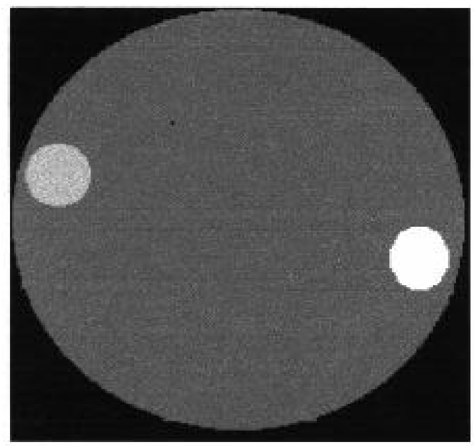
b. An example of Broyden Method, Simulated



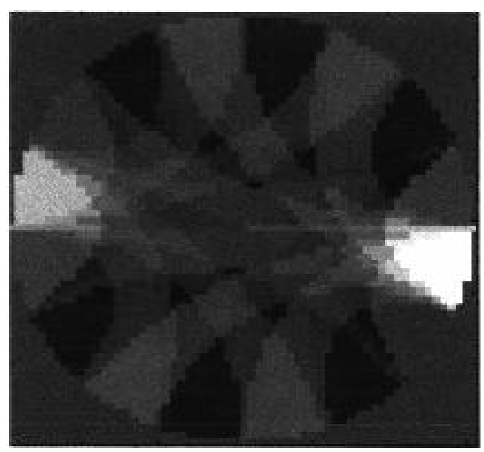
c. Sensitivity method, simulated



d. Newton-Raphson method, simulated



e. The model of phantom with $\rho1=150$ & $\rho2= 15\ \Omega.m$



f. A reconstructed image of e in APT with 16 electrodes using BP(real data)

Fig. 3. Some reconstructed images by simulation and also real data